EVALUATION OF GEOMETRIC DISTORTION IN MRI-ONLY INTERSTITIAL BRACHYTHERAPY IN TREATMENT PLANS AT 3 TESLA

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Introduction

- MRI is increasingly being adopted for gynecological brachytherapy (BT) due to superior soft tissue visualization and the potential to support MRI-only treatment planning[1].
- Eliminating CT may reduce multimodal imaging uncertainty and improve clinical efficiency[2].
- Geometric distortions in MRI are known to increase with distance from the magnetic isocentre[3].
- Spatial accuracy is particularly relevant for procedures involving laterally displaced needles.
- The Syed-Neblett template may involve positioning needles at a larger peripheral extent from the vaginal axis (>5 cm peripherally), potentially increasing distortion-related reconstruction uncertainties.

How does geometric distortion in 3 T MRI change with increasing distance from isocentre in interstitial brachytherapy cases?

Methods

- MRI geometric distortion was evaluated using an interstitial (IS) gel phantom (Figure 1a) containing embedded BB fiducials at known locations to provide geometric reference.
- CT, T1- and T2-weighted MRI were acquired.
- CT served as the geometric ground truth.
- Point-to-reference distances between IS needles and BBs were measured on each image set.
- MRI measurements were compared with CT to quantify geometric distortion.
- Distortion was evaluated as a function of radial distance from magnetic isocenter.

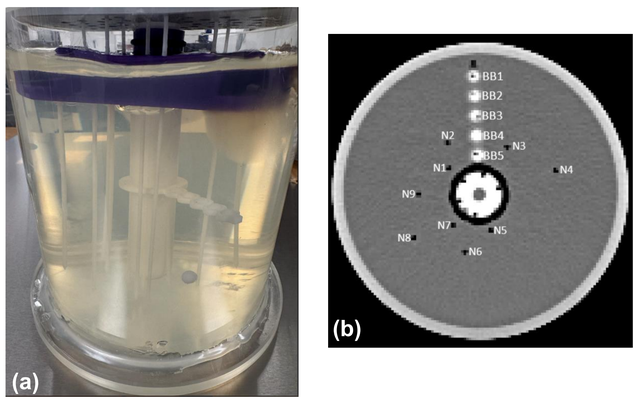

Figure 1. (a) Interstitial gel phantom containing Syed-Neblett template and BB fiducials. **(b)** CT image of phantom providing labelling of needles and BB reference.

Results

- MRI geometric distortion increased with radial distance from isocentre for both T1- and T2-weighted imaging (Figures 2 and 3).
- Linear regression demonstrated a positive relationship between radial distance and distortion for all evaluated needles (Table 1), indicated on the graph as the dashed trendlines.
- Individual needle trendlines demonstrated some variability in distortion magnitude, although all followed the same overall increasing trend.
- T1-weighted imaging demonstrated distortion slopes ranging from 0.0007 to 0.0436 mm/mm.
- T2-weighted imaging demonstrated distortion trends ranging from 0.0055 to 0.0185 mm/mm.
- The largest distortions were generally observed at greater radial distances from isocentre.

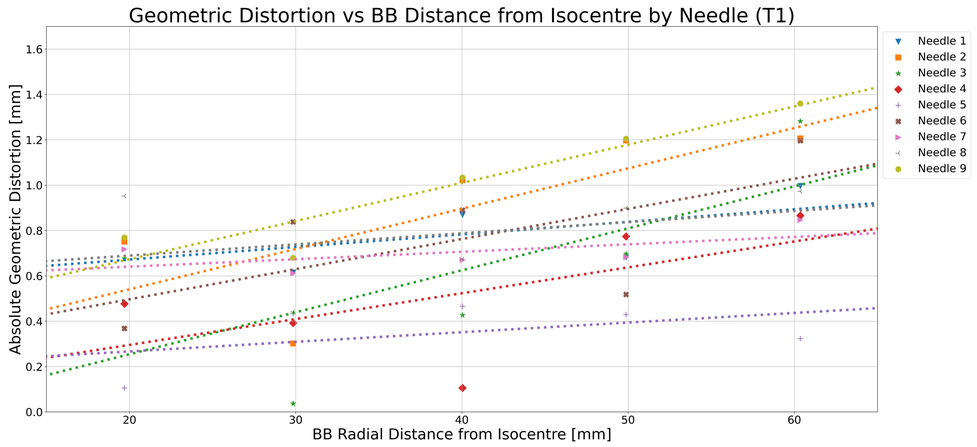

Figure 2. Distortion increased approximately linearly with radial distance from isocentre.

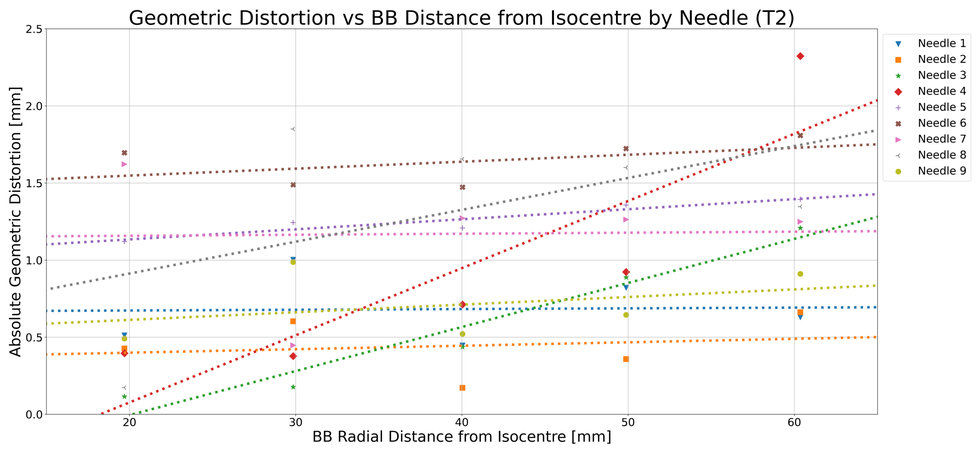

Figure 3. Similar distortion trends were observed for T2-weighted imaging, with lower variability between needle measurements.

	Linear Distortion Slopes for Each Needle (mm/mm)	
Needle Number	T1	T2
1	0.005	0.0055
2	0.0022	0.0178
3	0.0286	0.0185
4	0.0436	0.0114
5	0.0065	0.0042
6	0.0045	0.0133
7	0.0007	0.0033
8	0.0207	0.0049
9	0.0049	0.0168

Table 1. Linear distortion slopes (mm/mm) for each needle in T1- and T2-weighted MRI.

Discussion

- Geometric distortion increased with radial distance from isocentre for both T1- and T2-weighted MRI.
- Variability between needle trends suggests distortion is influenced by factors beyond radial distance alone.
- All measured distortions remained below the 2 mm tolerance generally considered clinically acceptable for high-dose-rate BT[4], supporting continued development of MRI-only workflows.

Conclusion

- MRI geometric distortion remained within clinically acceptable limits across the investigated treatment region.
- These findings establish a foundation for validating MRI-only Syed-Neblett reconstruction and clinical implementation of MRI-only gynecological brachytherapy.

Quantifying MRI geometric distortion provides confidence that MRI-only interstitial brachytherapy can be advanced with clinically acceptable geometric accuracy.

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More Info

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References

1. Dimopoulos J, Petrow P, Tanderup K, et al. Recommendations from Gynaecological (GYN) GEC-ESTRO Working Group (IV): Basic principles and parameters for MR imaging within the frame of image based adaptive cervix cancer brachytherapy. *Radiotherapy and Oncology*. 2012;103(1):113-122.
2. Chan K, Ballantyne H, Liu Z, et al. Intra-operative process efficiency for in-room MRI-guided combined intracavitary/interstitial brachytherapy for cervical cancer. *Brachytherapy*. 2024;24(5):729-737.
3. Siebert T, White S, Kim G, et al. Distortion inherent to magnetic resonance imaging can lead to geometric miss in radiosurgery planning. *Practical Radiation Oncology*. 2016;6(6):e319-e328.
4.Prisciandaro J, Zoberi J, Cohen G, et al. AAPM task group report 303 endorsed by the ABS: MRI implementation in HDR brachytherapy—Considerations from simulation to treatment. *Med Phys*. 2022;49:e983-e1023

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